PLASMA CLEANING DEVICE

Background of the Invention

Field of the Invention

The present invention relates to a plasma cleaning device for cleaning a process target disposed in a chamber with a plasma which is generated in the chamber under a reduced pressure with a high frequency voltage.

The plasma cleaning device has been used to achieve an object to remove a contaminant attached on surfaces of various kinds of objects made of a metal, an insulating material and others, and to activate the surfaces thereof to thereby increase wettability in various fields including an electronics field and others.

Description of the Background Art

A plasma cleaning device works in such a manner that a process gas is introduced into a vacuum chamber to produce an environment under a reduced pressure lower than the atmospheric pressure, a high frequency voltage is applied between an active electrode connected to a high frequency power supply and an earth electrode grounded or the chamber to generate a plasma and a process target disposed in the chamber is cleaned with the plasma. The plasma cleaning device has been expected as replacement of cleaning using a cleaning liquid such as a freon substitute (see JP A 2002-141324, JP A 2002-153832, JP A 2002-126675, JP A 2002-126674 and others).

Included in a plasma are ions, electrons, radicals, ultraviolet and others and those contribute to cleaning of a process target. Included in the chamber is the active electrode connected to the high frequency power supply, and a plasma is generated between the active electrode and the chamber connected to the earth potential or between the active electrode and an opposite electrode at the earth potential provided opposite the active electrode. A process target is generally disposed opposite the active electrode in a space in

which a plasma is generated.

As a plasma cleaning device in a different mode, there have been exemplified one in which an earth electrode in the shape of a lattice is used and a process target is disposed at the other side of the earth electrode from the active electrode.

In a method in which a process target is disposed in a space between an active electrode and an earth electrode or at a position opposite the active electrode in a chamber, the process target is, as has been generally performed in a prior practice, directly exposed to a plasma generated between both electrodes. In this method, the process target is heated to a high temperature and a material of the process target has a risk to be modified in property.

In a method in which a disposing position of a process target is selected in the back surface side of an earth electrode outside a space between opposite electrodes of a pair, ions in a plasma do not work effectively on the process target, leading to a fault of a very small cleaning effect to be exerted.

In the prior art methods described above, generally, oxygen, nitrogen, argon or hydrogen have been used as a process gas, while a chemically active gas has also been used because of a possibility with insufficiency of a cleaning effect of the former process gases.

Summary of the Invention

It is an object of the present invention to provide a plasma cleaning device a cleaning effect of which is raised while suppressing heating a process target to a high temperature.

The present invention is directed to a plasma cleaning device in which a process gas is introduced into a chamber including a pair of an active electrode connected to a plasma generating power supply and an earth electrode grounded, which electrodes are opposite each other, a plasma is generated in the chamber under a reduced pressure lower than the atmospheric pressure and a process target disposed in the chamber is cleaned with the plasma,

wherein a disposing position of the process target is selected outside a space between the opposite electrodes, and an electrically conductive path is connected to the process target.

That is, the plasma cleaning device of the present invention includes: a chamber for cleaning a process target disposed therein with a plasma, the chamber having an exhaust mechanism evacuating the chamber to a reduced pressure therein lower than the atmospheric pressure, a process gas introducing mechanism for introducing a process gas into the chamber, opposite electrodes of a pair of an active electrode and an earth electrode grounded which are housed in the chamber, a plasma generating power supply connected to the active electrode for supplying a power supply for use in generating the plasma in the chamber, a disposing position of the process target for disposing the process target outside a space between the opposite electrodes, and an electrically conductive path connected to the process target.

By disposing the process target not in the space between the opposite electrodes, but outside the space, the process target has no chance to be exposed directly to the plasma generated in the space, with the result that the process target has no possibility to be heated to a high temperature.

Furthermore, by connecting the electrically conductive path to the process target, it is prevented from occurring that the process target is charged and ions in the plasma are easy to act on the process target, which increases a cleaning effect. With such a construction adopted, a sufficient cleaning effect can be achieved without employing a chemically active gas as the process gas. As a result, air can be used as the process gas without imposing a burden on the environment and the cleaning is performed simultaneously at a low running cost.

For frequencies for the plasma generating power supply connected to the active electrode, an RF frequency of 13.56 MHz, which is called as an IMS frequency band and allowed for use in high frequency facilities, with a priority, other than those associated with communication, microwaves such as 2.45 GHz

and a low frequency band less than 10 KHz are available.

The disposing position of the process target is preferably at the other side of the earth electrode from the active electrode. With the process target at such a position, a high cleaning effect on the process target can be realized while the process target is prevented from being heated at a high temperature.

The electrically conductive path is preferably provided with an auxiliary power supply applying a potential to the process target. The potential of the process target is set by the auxiliary power supply to thereby cause ions in the plasma to more effectively act on the process target.

The auxiliary power supply may be of either a DC power supply or an AC power supply. Usable as an AC power supply is a commercial power supply of 50 or 60 Hz, or a low frequency power supply of less than 10 KHz. Change-over is allowed to be made between a DC power supply and an AC power supply as the auxiliary power supply.

In a case where the process target is an insulating material such as glass, CaF_2 or the like, an AC power supply as the auxiliary power supply is more effective than a DC power supply.

In a case where the auxiliary power supply is a DC power supply, it is preferable that the output potential thereof is variable. With the variability thereof, a level at which ions in a plasma act on the process target can be controlled.

In a case where the electrical conductive path is provided with the auxiliary power supply, a resistor is preferably connected between the auxiliary power supply and the process target. With such a configuration adopted, the current flowing from the process target to the earth potential can be adjusted, thereby enabling adjustment of a cleaning capability exerted on the process target.

In a case where the electrically conductive path is provided with the auxiliary power supply, a diode is preferably connected between the auxiliary power supply and the process target so that the process target side thereof is

an anode thereof. With such a configuration adopted, the process target can be charged at a minus potential, thereby facilitating plus ions in the plasma to act on the process target with the higher cleaning capability resulted.

In a case where the electrically conductive path is provided with the auxiliary power supply, the auxiliary power supply is preferably provided with a protective circuit against a current flowing thereinto from the process target. Examples of the protective circuit are a resistor connected in parallel to the auxiliary power supply and a parallel circuit of a resistor and a capacitor connected in parallel to the auxiliary power supply.

In the chamber, there can be disposed an insulating cover, with an opening through which the process gas flows, and which covers the pair of the opposite electrodes and the disposing position of the process target. The plasma is generated in a limited space obtained by partitioning with the insulating cover and confined in the space, which increases concentrations of ions and radical species arriving at the process target, thereby enabling a treatment effect on the process target to be enhanced.

In a common chamber, there can be disposed plural sets of the pair of the opposite electrodes and the disposing position of the process target. In such a case, the space in the chamber is preferably partitioned into subspaces so that the plasma is generated by each of the sets in a corresponding subspace independently of the other sets. The electrically conductive path is connected to the process target of each of the sets.

In this case, the active electrode of each of the sets is preferably connected to the plasma generating power supply through a respective resistor. With such a configuration adopted, prevention can be achieved of non-uniformity among currents flowing into the active electrodes of respective plural sets.

An inlet port for the process gas is preferably provided to a chamber vent pipe. In this case, as detailed in an embodiment, a power consumption is lower and in addition, more effective in raising a treatment effect on the process

target, compared with a case where the process gas is introduced into between the opposite electrodes.

Preferably further provided is a reflecting electrode in an electrically floating state at the other side of the active electrode from the earth electrode. With such a configuration adopted, more of the plasma can be moved in the direction of the earth electrode, thereby enabling a cleaning effect on the process target disposed in the earth electrode side to be enhanced.

Brief Description of the Drawings

Fig. 1 is a schematic perspective view showing an embodiment.

Figs 2A to 2J are circuit diagrams showing examples of electrically conductive paths.

Fig. 3 is waveform diagrams showing potentials of a process target and a curve “a” is a waveform diagram in a case where a set potential of an auxiliary power supply is DC 0V while a curve “b” is a waveform diagram in a case where a set potential of the auxiliary power supply is DC − 48 V.

Figs. 4A and 4B are waveform diagrams showing potentials of a process target in respective cases where no diode is provided to an electrically conductive path and where a diode is provided to the electrically conductive path.

Figs. 5A and 5B are circuit diagrams showing example protective circuits of an auxiliary power supply provided to an electrically conductive path.

Fig. 6 is a simplified diagram of a configuration showing an embodiment in which plural process targets are disposed for one pair of electrodes.

Fig. 7 is a simplified diagram of a configuration showing an embodiment in which plural electrode pairs are provided in one common chamber.

Fig. 8 is a simplified diagram of a configuration showing another embodiment in which plural electrode pairs are provided in one common chamber.

Fig. 9 is a schematic diagram showing an example provided with an

insulating cover enclosing a pair of electrodes and a process target.

Description of the Preferred Embodiments

Concrete description will be given of the present invention using embodiments below.

Fig. 1 shows an embodiment schematically. A numerical symbol 2 indicates a vacuum chamber, which is connected to a vacuum pump via a vent pipe 4. Provided to the vent pipe 4 are a valve 6 for setting an exhaust speed of the vacuum pump at a proper value and a valve 8 constituting a process gas introducing mechanism for introducing a process gas. A flow rate of the process gas introduced is adjusted by an opening degree of the valves 6 and 8 to thereby control a pressure in the chamber 2. The exhaust mechanism is constituted of the vacuum pump and the valve 6. In a case where the space in the chamber 2 is opened to the outside atmosphere, the air is introduced into the chamber through a leakage valve not shown. The bottom of the chamber 2 is made of metal and grounded.

Disposed in the chamber 2 are an active electrode 12 and an earth electrode 14 opposite each other. The active electrode 12 is connected to a plasma generating power supply 16 and supplied with a voltage with a frequency of 1 KHz or 13.56 MHz. The earth electrode 14 is supported by a support 18 and connected to the bottom of the chamber so as to take the earth potential. A numerical symbol 20 is another electrode in an electrically floating state and the electrode 20 is opposed to the active electrode 12 and at the other side of the active electrode 12 from the earth electrode 14. The electrode 20 acts as a reflecting plate to move back a plasma generated between the active electrode 12 and the earth electrode 14 toward the earth electrode 14 side.

A disposing position of a process target 22 is selected at the other side of the earth electrode 14 from the active electrode 12. The process target 22 is supported by the support 18 and a part of the support 18 supporting the process target 22 is made of an insulating material and the process target 22 is

supported in a state where no electrical connection is established with the bottom of the chamber bottom. It is assumed here that the process target 22 is made of a metal. The process target 22 is connected to an electrical conductive path 24 which is grounded via a resistor 26 and an auxiliary power supply 28. The auxiliary power supply 28 in this embodiment is a DC power supply wherein an output potential is variable. A numerical symbol 30 is an ammeter provided for measuring a current flowing through the electrically conductive path 24.

In a case where an insulating object is used as the process target 22, the part of the support 18 supporting the process target 22 is of a metal and the part is connected to the electrically conductive path 24.

A disposing position of the process target 22 is not limited to the case in which it is disposed at a position at the other side of the earth electrode 14 from the active electrode 12, as shown in this embodiment. The disposing position has only to be selected outside a space between the active electrode 12 and the earth electrode 14, avoiding the space. If the process target is excessively close to the active electrode 12, however, a discharge is unpreferably occurs from the active electrode 12 to the process target 22.

In a case where the process target 22 is disposed at the other side of the earth electrode 14 from the active electrode 12 as in this embodiment, a plasma is moved away in the direction of the earth electrode 14 by the action of the electrode 20 serving as the reflecting plate and more of the plasma acts on the process target 22, enhancing an cleaning effect.

In this embodiment, a potential of the process target 22 is set at a predetermined potential, for example a minus potential, by the action of the auxiliary electrode 28, a process gas is introduced into the chamber 2 to keep a vacuum degree of the order 100 Pa in the chamber 2 and a voltage is applied to the active electrode 12 from the power supply 16, whereby a discharge occurs between the active electrode 12 and the earth electrode 14 to generate a plasma and the plasma acts on the process target 22 to clean or activate a

surface thereof.

Air can be used as the process gas in the present invention. In a prior art plasma cleaning device, almost no cleaning effect was able to be expected if air was used as the process gas, while according to the present invention, air can achieve a sufficient cleaning effect without using a chemically active gas instead, leading to a great advantage in respect of no discharge of a harmful gas to the environment as well. It is natural that oxygen, argon, nitrogen, hydrogen and the like may be used as the process gas as in a prior art practice.

In a prior art plasma cleaning device, generally, a process gas was introduced into a chamber between opposite electrodes and a plasma generated there was carried on a stream of the process gas to arrive at a process target. Since, with such a construction adopted, however, the whole of a raw gas flows into the space, concentrations of ions and radical species are low in the plasma. Therefore, as shown in Fig. 1, an inlet port of the process gas is provided to the vent pipe 4. An inflow gas is immediately reduced to a pressure in the chamber and diffuses into the space between the electrodes 12 and 14 and a plasma region of the process target 22 in the reduced pressure state. Power consumption is low since a great part of the raw gas are discharged through the vent pipe 4 and less power is consumed for generating a plasma from the raw gas.

Furthermore, since suppression occurs of neutralization of a plasma by the raw gas reaching the plasma space, concentrations of ions and radicals in the plasma are increased, thereby enabling a treatment effect on the process target to be enhanced.

On the other hand, it is important that a contaminant component removed from the surface of the process target is efficiently discharged from the plasma region. In view of both cleaning and activation of the surface, therefore, it is practical to optimally select a disposing position or positions of gas inlet ports and the number thereof.

Various modifications or alterations can be possible on the electrically

conductive path 24. Figs. 2A to 2J show some exemplary electrically conductive paths.

Fig. 2A is an example in which a DC power supply 28 is provided as an auxiliary power supply to the electrically conductive path 24, wherein the plus side of the output terminal of the power supply 28 is grounded, while the minus side is connected to the process target 22. The power supply 28 shows one of a variable output potential, while it may also be of a constant output potential.

Fig. 2B is an example in which an AC power supply 32 is provided as an auxiliary power supply to the electrically conductive path 24.

Fig. 2C is an example in which a DC power supply 24 and a resistor 26 are provided to the electrically conductive path 24 as shown in the embodiment of Fig. 1. Fig. 2D is an example in which an AC power supply 32 as an auxiliary power supply and a resistor 26 are provided to the electrically conductive path 24.

In the cases where the resistor 26 together with the auxiliary power supply is provided to the electrically conductive path 24 as shown in Figs. 2C and 2D, a current flowing between the process target 22 and the earth potential can be suppressed and controlled by adjusting a resistance value of the resistor 26.

An effect of the resistor 26 provided is as follows: A current flowing through the process target 22 can be suppressed and controlled by the resistor 26 as a parameter independent of an intensity of a plasma generated between the active electrode 12 and the earth electrode 14, a vacuum degree, a voltage of the auxiliary power supply 28, a disposing position of the process target 22 and others. As a result, increase in temperature can be restricted to a low level while ensuring a proper treatment effect on the process target 22.

The resistor 26 has another effect to prevent generation of a corona discharge easy to occur on the process target 22 in a plasma. Generally, in the discharge circuit, it has been common to provide a corona discharge prevention protective resistor. When a corona discharge occurs and an overcurrent flows,

a voltage drop of ((a resistance value) x (a current value)) is brought about by the resistor 26 and an applied voltage is reduced, thereby enabling a corona discharge to be automatically annihilated. A resistance value of the resistor 26 is preferably in the range of hundreds of Ω to thousands of Ω as a result of an experiment and a corona discharge can be prevented by the resistor 26 in the range; thereby enabling treatment of the process target without heating it.

Then, description will be given of an effect of a potential applied to the process target 22 in a case where a DC power supply is used as the auxiliary power source 28. Fig. 3 shows waveforms obtained by monitoring potentials of the process target 22 in Fig. 1 with an oscilloscope. The waveform indicated with "a" in the figure is one in a case where an output voltage of the power supply 28 is set at DC 0 V. A positive ion current in the direction to the earth potential from the process target 22 and a negative current in the direction to the process target 22 form the earth potential are generated alternately on the time axis, however, the positive ion current is larger than the negative current in time average value in a case where an output voltage of the power supply 28 is set to 0 V. Therefore, a wave diagram area value on the plus direction is larger than that on the negative direction.

On the other hand, in a case where a potential of the process target is driven to a minus potential by the auxiliary power supply 28, a waveform shifts in the minus direction as shown with a curve "b" in Fig. 3. If a DC voltage value on the minus direction is increased, the whole of a waveform shifts in the minus direction and there exists a voltage set value at which a wave diagram area value in the plus direction is almost equal to that in the minus direction. If a DC minus voltage value is further increased in the minus direction, a wave height peak value in the plus direction finally reaches not a plus value but 0 V and a wave height peak value in the minus direction takes almost a DC minus voltage value at this time.

If the process target 22 is surrounded with ions in a plasma and charged, the ions around the process target 28 are repelled by the charge voltage, losing

an etching effect due to ion collision. Therefore, no charge occurs on the process target 28 by setting a potential of the process target 22 to a minus potential so that the potential of the process target takes 0 V in time average value on the time axis. In a case where the process target is of an insulating material, by using a support, on which the process target 22 rests, made of an electrically conductive material and by connecting the support to the electrically conductive path 24, a potential on a surface of the process target can also be caused to be 0 V in average on the time axis and no charge can be caused on the process target 22. As a result, even if the process target is of an insulating material such as CaF_2, a surface etching effect and a cleaning effect can be enhanced.

In a case where a potential of the auxiliary power supply is set so that a potential of the process target 22 always takes a minus potential and a wave height peak value in the plus direction takes 0 V on the time axis, a wave height peak value in the minus direction takes almost a DC minus voltage value at this time; therefore, a potential of the process target 22 oscillates between the wave height peak values above and below the time average value as the center. Therefore, a surface of the process target 22 always takes a minus potential, whereas no charge occurs thereon. With a deeper minus potential of the process target 22 adopted, a stronger cleaning effect can be attained.

With reference to Figs. 2A and 2J, description will be given of other examples of the electrically conductive path 24. Figs. 2E and 2F are examples in which a diode 34 is connected so that the process target 22 side thereof is the anode. Figs. 2G and 2H are examples in which a resistor 26 is further connected in series. The diode 34 and the resistor 26 may be interchanged over positions thereof.

With the diode 34 connected, it is prevented to generate a current flowing in the direction from the earth potential to the process target 22, that is a negative current due to collision of electrons and negative ions to the process target 22. A positive ion current due to collision of positive ions to the process

target 22 flows in the direction from the process target 22 to the earth potential, that is in the forward direction of the diode 34. By this action, the process target 22 is more deeply charged in the minus direction compared with a case of a construction without the diode 34 connected in a cycle in which the process target 22 is charged in the minus direction by a plasma. This is because in the case without the diode 34 connected, when the process target 22 is charged in the minus direction, a current flows in the direction of neutralization of the minus potential, that is in the direction from the earth potential to the process target 22. In a case with the diode 34 connected, no current of neutralization of the minus potential flows and the minus potential of the process target 22 is not neutralized with the result that the process target 22 is charged to the deeper minus potential.

Figs. 4A and 4B show the effect of the diode by using waveforms obtained in observation of potentials of the process target 22 with an oscilloscope. Fig. 4A shows the effect in the case without the diode 34. Fig. 4B shows the effect in the case with the diode 34 connected, wherein depression in the minus direction is observed, which causes the process target 22 to be charged to a minus potential.

More of plus ions collide to the process target 22 in a cycle in which the process target 22 is charged in the plus direction and in addition, a speed of collision increases compared with a construction without the diode 34 connected. This is because, the process target 22 is charged to a deeper minus potential compared with the case without the diode 34 connected; therefore, plus ions are attracted to the minus potential. In such a way, increase occurs in amount and speed of plus ions in collision with the process target 22.

With such an action exerted, a cleaning effect on the process target 22 is enhanced by the diode 34 connected. Since neither an electron current nor a minus ion current flows, an applied power to the process target 22 decreases and an increase in temperature is also reduced. In a case where the auxiliary

power supply is the DC power supply 28, the diode 34 connected prevent a reverse current from flowing into the output terminal of the DC power supply 28, which also leads to an effect of protecting the DC power supply 28 from the reverse current.

Again, with respect to Fig. 2I, description will be given of still another example of the electrically conductive path 24.

In Fig. 2I, none of the auxiliary power supplies 28 and 32 is provided but the resistor 26 is provided. The process target 22 is charged by the plasma even without the auxiliary power supply and a current flows between the process target 22 and the earth potential through the resistor 26 in the electrically conductive path 24 connected to the process target 22. In this case, if the process target 22 is disposed near the earth electrode, a positive ion current in the direction from the process target 22 to the earth potential and a negative current in the direction from the earth potential to the process target 22 are alternately generated on the time axis, wherein the positive ion current flows more in time average value than the negative current.

Since a current value decreases in a case without an auxiliary power supply, a plasma treatment effect becomes low, but an almost sufficient cleaning capability can be exerted in a practical sense.

As shown in Fig. 2J, in a case where the diode 34 is connected in series with the resistor 26, the treatment effect is improved.

In a case where the electrically conductive path 24 is not provided with an auxiliary power supply as shown in Figs. 2I and 2J, the plasma cleaning device is simplified because of no auxiliary power supply connected.

In a case where the DC power supply 28 is used as the auxiliary power supply, there is a risk of a failure according to an internal configuration of the power supply because of inflow of a reverse current and a pull-in current. While plus and minus currents flow in the direction from the process target 22 to the earth potential, it is preferable in any of both cases that neither the reverse current nor the pull-in current occurs relative to the DC current power

supply 28.

Therefore, Figs. 5A and 5B show examples in each of which a protective circuit is provided to the auxiliary power supply 28 in the electrically conductive path 24. Fig. 5A is a circuit in which the resistor 36 is connected in parallel to the power supply 28 and Fig. 5B is a circuit in which the resistor 36 and a capacitor 38 are individually connected in parallel to the power supply 28.

In the protective circuit of Fig. 5A, a sufficient initial current is caused to flow between the plus and minus output terminals of the power supply 28 in advance with the help of the resistor 36. To be concrete, for example, if in a case where the output terminal voltage of the power supply 28 is set to 50 V and a DC average current of the process target is set to 10 mA, a dummy current (20 mA) about twice as much as 10 mA of the DC average current is caused to flow between the terminals, a necessary resistance value R as the resistor 36 is given as follows:

$$R = 50\ \mathrm{V}/20\ \mathrm{mA}$$
$$= 2.5\ \mathrm{k\Omega}$$

There can be a risk of a failure according to a construction of the power supply 28 by flowing of a high frequency current of a frequency of a plasma into the DC output thereof. As a countermeasure, as in Fig. 5B, it is effective to connect the capacitor 38, for example a ceramic capacitor. A proper concrete example is a capacitor with a capacitance value of 0.01 μF and a withstand voltage is in the range of from 500 to 1000 V.

Fig. 6 shows an example in which a pair of electrode 12 and 14 in a chamber 2, plural process targets are disposed in the chamber 2 and electrically conductive paths 24 are connected to the respective process targets 22-1 to 22-n or a group of the process targets. In this case, resistors 26-1 to 26-n are preferably provided to respective electrically conductive paths 24-1 to 24-n. In a case, non-uniformity in plasma concentration occurs at individual disposing positions of the process targets 22-1 to 22-n depending on a plasma concentration distribution. In order to cope with such a non-uniformity,

resistance values of the resistors 26-1 to 26-n are adjusted to thereby enable currents flowing between the process targets 22-1 to 22-n and the earth potential to be suppressed or controlled, thereby enabling suppression of non-uniformity in treatment caused by location-dependence of non-uniformity in plasma distribution.

Fig. 7 shows an example in which disposed in one chamber 2 are plural sets of a pair of electrodes and a process target (process targets). The internal space of the chamber 2 is partitioned into subspaces for respective sets, and the sets each of one from pairs of electrodes 12-1 to 12-n and corresponding electrodes 14-1 to 14-n, and a corresponding one from process targets 22 are disposed in the respective subspaces. Insulating barriers 40 are disposed between the subspaces so that plasmas in the subspaces are generated independent of the others. In a case where the side wall of the chamber 2 is not of an insulating material, the subspaces are preferably enclosed with an insulating material.

The active electrodes 12-1 to 12-n are connected in parallel each other to a common plasma generating power supply 16 through the respective resistors 42-1 to 42-n. In a case where in such a way, the plural plasma generating active electrodes are disposed in the common chamber 2, plasma impedances in the respective treatment subspaces change by various kinds of factors such as a process gas pressure, a flow direction of a process gas, a temperature thereof and positional relationships of the electrodes 12-1 to 12-n with the inner walls of the respective treatment subspaces. Therefore, if the plural electrodes 12-1 to 12-n are connected to one plasma generating power supply 16 in parallel each other, it becomes difficult to make plasma generating concentrations uniform at the respective electrodes 12-1 to 12-n. In addition, if a current flow in one of the electrodes 12-1 to 12-n more than in the other electrodes 12-1 to 12-n, a process gas temperature at the one electrode is higher than at the others with result that a plasma impedance there decreases and thereby, a current is concentrated into the one electrode, while extremely

low plasma generating concentrations are obtained at the other electrodes, thereby degrading uniformity over plasma concentrations in the plural treatment subspaces.

Therefore, the resistors 42-1 to 42-n are provided and if a current flows in one of the electrodes 12-1 to 12-n more than in the others, a voltage drop ((a current) x (a resistance value)) occurs to thereby lower a supply voltage to the one electrode. As a result, the supply voltage is automatically corrected in the direction in which a current returns to a normal value. Since in such a way, a current concentration to a particular electrode is prevented and an individual current can be adjusted and set, non-uniformity in plasma distribution over the subspaces can be suppressed.

Fig. 8 shows an example in which plural sets of an electrode pair and a process target (or process targets) are disposed in one chamber 2 in similar manner to the case of Fig. 7. Sets of a pair of electrodes and a process target are disposed in respective subspaces obtained by partitioning with insulating cylinders 44-1 and 44-2. Plasmas can be generated in the subspaces obtained by partitioning with the insulating cylinders 44-1 and 44-2, thereby enabling treatment effects on process targets to be increased.

Fig. 9 shows an example in which a pair of electrodes 12 and 14 and a process target 22 is disposed in one chamber 2 and those are enclosed with an insulating cover 46. The insulating cover is not to seal the interior thereof and an opening 48 is formed in part of the cover 46 the interior of which communicates with the outer space portion in the chamber 2. A process gas flows through the opening 48.

A plasma is generated in the smaller space obtained by partitioning the space in the chamber 2 with the insulating cover 46 and the plasma is confined within the smaller space, thereby enabling increase in concentrations of ions and radicals in the plasma traveling to and arriving at the processing target 22 and further enabling a treatment effect on the process target to be enhanced.

In a case where the insulating cover 46 is not available and the space in

the chamber 2 is vast, ions and radicals in a plasma generated diffuses toward the inner wall thereof. Especially, in a case of a prior art chamber in which the chamber was made of an electrical conductive material such as a metal and assumes the earth potential, plus ions were attracted to the earth potential; therefore, a concentration of the plus ions arriving at the process target decreased, having reducing a treatment efficiency.